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10      **SUSPENSION SYSTEM HAVING REDUCED STRESS**  
         **AXLE CONNECTION**

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**BACKGROUND**

20      The present invention relates generally to vehicle suspension systems and,  
in an embodiment described herein, more particularly provides a suspension  
system having a reduced stress axle connection.

It is well known in the suspension system art to weld an arm to an axle of  
the suspension system. Due to the requirements of manufacturing tolerances  
25 and economy, typically some clearance is provided between the axle and the arm.  
Unfortunately, this clearance between the axle and arm leads to relatively weak

welds, for example, having reduced fatigue strength. This clearance between the axle and arm also increases the stress in the welds, leading to premature failure of the welds.

It has been proposed to reinforce the axle by means of a sleeve interposed  
5 between the axle and arm. In one such proposal, the sleeve is press-fitted on the axle to reduce the clearance therebetween, but this adds steps to the manufacturing process, requires additional special equipment, requires exceptionally close machining tolerances, etc. In another such proposal, the sleeve is made in multiple segments which are assembled about the axle prior to  
10 being welded to the axle, but this complicates the manufacturing process and also requires additional special equipment and steps to assemble the sleeve segments about the axle, without resolving the problem of clearance between the axle and the member(s) welded thereto.

From the foregoing, it can be seen that it would be quite desirable to  
15 provide a suspension system and associated manufacturing process which reduce the stress in an axle connection by removing the clearance between the axle and a sleeve welded to the axle. Such a suspension system and manufacturing process would preferably also provide for welding an arm to an axle without welds being positioned in high stress areas.

## SUMMARY

In carrying out the principles of the present invention, in accordance with  
5 an embodiment thereof, a suspension system is provided which includes a sleeve  
welded to an axle and an arm of the suspension system. Methods of fabricating  
the suspension system are also provided.

In one aspect of the invention, a vehicle suspension system is provided  
which includes an axle, a sleeve and an arm. The sleeve is clamped on the axle  
10 without press-fitting, and the sleeve is welded in its clamped position. The axle  
may also be welded to the sleeve in its clamped position. The arm is attached to  
the axle by welding the arm directly to the sleeve.

In another aspect of the invention, the arm has opposing side walls. Each  
of the side walls has an opening formed therethrough. The sleeve is received in  
15 each of the openings, and the sleeve is welded to the arm less than 360 degrees  
about a periphery of each of the openings.

In yet another aspect of the invention, a method of fabricating a vehicle  
suspension system is provided. The method includes the steps of clamping a  
sleeve to an axle without press-fitting; welding the sleeve, thereby retaining the  
20 sleeve in its clamped position; and welding the sleeve to each of opposing side  
walls of an arm, the sleeve being welded less than 360 degrees about an opening  
formed through each of the side walls.

In a further aspect of the invention, the step of clamping the sleeve to the axle removes clearance between the sleeve and axle, and applies a compressive stress between the sleeve and axle. The clamping step may be performed by tightening a fastener in a clamp portion of the sleeve. The compressive stress  
5 between the sleeve and axle may be retained by welding members of the sleeve clamp portion to each other.

These and other features, advantages, benefits and objects of the present invention will become apparent to one of ordinary skill in the art upon careful consideration of the detailed description of representative embodiments of the  
10 invention hereinbelow and the accompanying drawings.

### **BRIEF DESCRIPTION OF THE DRAWINGS**

FIG. 1 is a side view of a suspension system embodying principles of the  
15 present invention;

FIG. 2 is a front elevational view of an axle/clamp subassembly of the suspension system of FIG. 1;

FIG. 3 is a side view of an arm subassembly of the suspension system of FIG. 1;

20 FIG. 4 is a front elevational view of an alternate axle/clamp subassembly of the suspension system of FIG. 1;

FIG. 5 is a top view of the alternate axle/clamp subassembly of FIG. 4;

FIG. 6 is a side view of the suspension system of FIG. 1 incorporating the alternate axle/clamp subassembly of FIG. 4;

FIG. 7 is a side view of a second suspension system embodying principles of the present invention;

5        FIG. 8 is a side view of a third suspension system embodying principles of the present invention;

FIG. 9 is a side view of a fourth suspension system embodying principles of the present invention;

10       FIG. 10 is a side view of a fifth suspension system embodying principles of the present invention;

FIG. 11 is a cross-sectional view of the fifth suspension system, taken along line 11-11 of FIG. 10;

FIG. 12 is a cross-sectional view of the fifth suspension system, showing an alternate configuration thereof; and

15       FIG. 13 is a cross-sectional view of the fifth suspension system, showing another alternate configuration thereof.

### DETAILED DESCRIPTION

20       Representatively illustrated in FIG. 1 is a portion of a vehicle suspension system 10 which embodies principles of the present invention. In the following description of the suspension system 10 and other apparatus and methods

described herein, directional terms, such as "above", "below", "upper", "lower", "top", "bottom", etc., are used only for convenience in referring to the accompanying drawings. Additionally, it is to be understood that the various embodiments of the present invention described herein may be utilized in various orientations, such as inclined, inverted, horizontal, vertical, etc., and in various configurations, without departing from the principles of the present invention.

The suspension system 10 includes an axle 12 attached to two trailing arms 14. Only one of the arms 14 is visible in FIG. 1. The suspension system 10 is of the type which has two trailing arms 14 pivotably attached at their forward ends to opposite lateral sides of a vehicle frame 16 (see FIG. 6), and attached at or near their rearward ends to the axle 12. It is to be clearly understood, however, that principles of the invention may be incorporated into other types of suspension systems having any number of arms.

The arm 14 includes a bushing sleeve 18 at its forward end for receiving a pivot bushing of the type well known to those skilled in the art. Extending rearwardly from the bushing sleeve 18 are four outer sides of the arm 14, the four sides including a top plate 20, two opposing side walls 22 (only one of which is visible in FIG. 1), and a bottom plate 24. The top plate 20 and side walls 22 are preferably formed from a single metal sheet which is bent so that it has a generally U-shaped cross-section.

The bottom plate 24 extends laterally between the side walls 22 and is welded to the side walls along a lower peripheral edge 26 of each side wall. The

bottom plate 24, top plate 20 and side walls 22 are also welded at their forward ends to the bushing sleeve 18. Of course, the arm 14 could be otherwise constructed without departing from the principles of the invention.

The axle 12 extends through a circular opening 28 formed through each side wall 22. Note that the opening 28 does not completely encircle the axle 12, however, since there is a void 30 extending between the opening 28 and the edge 26. These features of the arm 14 may be more clearly seen in FIG. 3, wherein the arm is illustrated prior to its attachment to the axle 12, bushing sleeve 18 and bottom plate 24.

In a unique aspect of the invention, the arm 14 is attached to the axle 12 using a sleeve 32 which is clamped to the axle. This clamping of the sleeve 32 to the axle 12 applies a compressive stress between the sleeve and axle, and removes clearance between the axle and sleeve. As a result, when the sleeve 32 is later welded to the axle 12, the welds are much stronger and have an increased fatigue strength.

Note that this result is obtained without the added expense of precise machining tolerances and specialized equipment required for press-fitting a sleeve onto an axle. The heating and/or cooling equipment and processes required for shrink-fitting are also not required.

Instead, the sleeve 32 of the suspension system 10 is clamped onto the axle 12 using fasteners 34, such as bolts, hucks, or any other type of fasteners, in a clamp portion 36 of the sleeve. The fasteners 34 may be seen in FIG. 2, wherein a

front view of the sleeve 32 and axle 12 is illustrated prior to the arm 14 being attached thereto. The fasteners 34 pass through holes 38 formed through the clamp portion 36.

In a preferred method of fabricating the suspension system 10, the sleeve 32 is positioned on the axle 12 and the fasteners 34 are tightened in the clamp portion 36 to remove clearance between the sleeve and axle. The sleeve 32 is then welded to the axle 12. Preferably, the sleeve 32 is first welded to the axle 12 about openings 40 formed through the sleeve.

The openings 40 are centered on opposite vertical sides of the sleeve 32.

In this manner, the sleeve 32 is welded to the axle 12 in a low stress area of the axle and reduces the effects of stress concentrations in the axle due to the welding. This combination of higher strength welds (due to removal of clearance between the sleeve 32 and the axle 12) and positioning of welds in low stress areas of the axle provides increased strength in the axle and in the sleeve-to-axle connection.

Note, however, that the sleeve 32 may also be welded to the axle 12 at opposite lateral ends 42 of the sleeve, for example, either partially or completely encircling the axle. Alternatively, if the clamping of the sleeve 32 onto the axle 12 produces a sufficient bearing load therebetween, no welding of the sleeve to the axle may be required.

After the sleeve 32 is welded to the axle 12, the sleeve is inserted into the openings 28 in the arm 14, and the arm is welded to the sleeve about the



openings. Note that the clamp portion 36 is received in the voids 30 when the sleeve 32 is inserted into the openings 28. To permit the clamp portion 36 to be received in the voids 30, the fasteners 34 may be removed from the clamp portion prior to inserting the sleeve 32. Other embodiments are described below in which it is not necessary to remove the fasteners 34 prior to inserting the sleeve 32 into the openings 28. Thus, it may be seen that the fabrication method of the present invention is not dependent upon any particular order of steps.

For increased strength in the axle 12 to arm 14 connection, the clamp portion 36 may be welded together, thereby retaining the compressive stress between the sleeve 32 and axle. In FIG. 1, a weld 44 is shown between two members of the clamp portion 36 extending outwardly from the void 30. It is not necessary, however, for the clamp portion 36 to be welded together in keeping with the principles of the invention.

The bottom plate 24 of the arm 14 is also preferably welded to the clamp portion 36 of the sleeve 32. Another bottom plate 46 extending between and attached to the side walls 22 may also be welded to the clamp portion 36. Note that the bottom plates 24, 46 may be welded to the side walls 22 along the edges 26 prior to inserting the sleeve 32 into the openings 28, or the bottom plates may be welded to the side walls and to the sleeve 32 after the sleeve is inserted into the openings.

For increased strength, the sleeve 32 substantially encircles the axle 12, extending substantially greater than 180 degrees about the axle. The openings 28

extend less than 360 degrees about the sleeve 32, and so the side walls 22 are welded less than 360 degrees about the sleeve. The edges of the void 30 may be welded to the clamp portion 36 to further strengthen the attachment between the sleeve 32 and arm 14.

5 Referring additionally now to FIGS. 4 & 5, an alternate sleeve 48 is representatively illustrated attached to the axle 12. The alternate sleeve 48 differs from the sleeve 32 described above in that it includes a laterally extending portion 50. Thus, the alternate sleeve 48 is substantially wider than the sleeve 32.

10 The portion 50 supplies a convenient location for mounting additional equipment, such as a shock absorber, to the sleeve 48. In this manner, the equipment may be rigidly attached to the axle 12 via the sleeve 48, without the necessity of also, or alternatively, attaching the equipment to the arm 14. This saves weight, enhances the efficiency of the manufacturing process and reduces  
15 stress in the arm 14 (as opposed to attaching such equipment to the arm, which typically requires substantial reinforcement of the arm).

Referring additionally now to FIG. 6, the suspension system 10 is representatively illustrated with the alternate sleeve 48 incorporated therein. The arm 14 is pivotably attached to a hanger bracket 52 extending downwardly  
20 from the vehicle frame 16. A bushing 54 is received in the bushing sleeve 18, thereby permitting the arm 14 to rotate and articulate somewhat relative to the

hanger bracket 52. An air spring 56 is positioned between the frame 16 and a rear portion of the arm 14.

A shock absorber 58 is interconnected between the hanger bracket 52 and the sleeve 48. For this purpose, a mounting bracket 60 is welded to the portion  
5 50 of the sleeve 48. Thus, it may be seen that the invention provides a convenient attachment of the shock absorber 58 to the axle 12, without requiring the shock absorber to be mounted to the arm 14.

Referring additionally now to FIG. 7, the suspension system 10 is representatively illustrated with an alternate arm 62 incorporated therein in  
10 place of the arm 14 described above. The arm 62 is very similar to the arm 14, but differs in at least one respect in that it includes a void 64 in at least one of its side walls 66 which is configured to permit the fasteners 34 to pass therethrough.

In this manner, it is not necessary for the fasteners 34 to be removed from the clamp portion 36 prior to inserting the sleeve 32 into the openings 28. Of  
15 course, other means of permitting the fasteners 34 to pass through the side walls 66 may be used without departing from the principles of the invention. For example, the fasteners 34 could be recessed into the clamp portion 36, etc.

The clamp portion 36 may still be welded together, for example, by the weld 44, even though the fasteners 34 are not removed from the clamp portion.

20 In addition, the bottom plates 24, 46 may still be welded to the clamp portion 36.

Referring additionally now to FIG. 8, the suspension system 10 is representatively illustrated with another alternately constructed arm 68. The arm 68 is very similar to the arm 14, but differs in one respect in that it has openings 70 in each of its side walls 72 which intersect, or are open at, lower peripheral edges 74 of the side walls. Thus, there are no separate voids 30  
5 extending between the openings 70 and the peripheral edges 74, but the voids may instead be considered part of the openings.

The openings 70 are closer to the lower edges 74, so that when the sleeve 32 is inserted into the openings, the fasteners 34 are below the side walls 72. This  
10 is another means by which it is not necessary for the fasteners 34 to be removed from the clamp portion 36 prior to inserting the sleeve 32 into the openings 70. This may also permit the bottom plates 24, 46 to be welded to the sleeve 32 above the clamp portion 36. The clamp portion 36 may also be welded together as described above, whether or not the fasteners 34 are removed.

Referring additionally now to FIG. 9, another alternate construction for the suspension system 10 is representatively illustrated. The shock absorber 58 is interconnected between the hanger bracket 52 and the axle 12 similar to the embodiment depicted in FIG. 6. However, instead of welding the shock mounting bracket 60 directly to a portion 50 of the sleeve 48, the mounting  
15 bracket is attached to the sleeve 32 by means of another bracket 76.  
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The bracket 76 may be welded to the clamp portion 36 of the sleeve 32. If desired, the bracket 76 may also be welded to the arm 68, for example, by

welding to the bottom plate 24. In that case, the bracket 76 may also serve to strengthen the attachment between the sleeve 32 and the arm 68.

Referring additionally now to FIG. 10, another alternate construction of the suspension system 10 is representatively illustrated. In this embodiment, a sleeve 78 is used which includes a specially adapted clamp portion 80. The clamp portion 80 permits the sleeve 78 to rotate within the openings 70 after being inserted therein.

The clamp portion 80 may be more clearly seen in the cross-sectional view depicted in FIG. 11. In this view, it may be seen that the clamp portion 80 includes two recesses 82 aligned with the side walls 72 of the arm 68. The recesses 82 permit the sleeve 78 to rotate within the openings 70 in the side walls 72.

When the sleeve 78 is inserted into the openings 70, the clamp portion 80 is positioned so that it extends downwardly as viewed in FIG. 10, so that the clamp portion passes through the voids between the openings and the lower edges 74 of the side walls 72. The recesses 82 are then aligned with the side walls 72 and the sleeve 78 is rotated until the clamp portion 80 extends upwardly. The sleeve 78 is welded to the arm 68 with the clamp portion 80 in its upward position. This upward positioning of the clamp portion 80 increases the ground clearance of the suspension system 10.

Note that the bottom plates 24, 46 may be welded to the side walls 72 after the sleeve 78 and side walls 72 are welded together, in order to provide access to

the sleeve between the side walls. The bottom plates 24, 46 may also be welded to the sleeve 78. The fasteners 34 may be removed, or they may remain in the clamp portion 80. The clamp portion 80 may be welded together as described above, whether or not the fasteners 34 are removed.

5           The side walls 72 of the arm 68 are parallel to each other as depicted in FIG. 11. However, it is not necessary for the side walls 72 to be parallel to each other. In FIG. 12, the arm 68 is depicted with an alternate construction in which the side walls 72 are each inclined inwardly toward the top plate 20, and inclined outwardly toward the bottom plate 46.

10           Note that the recesses 82 of the clamp portion 80 as depicted in FIG. 12 have been widened (as compared to the clamp portion 80 as depicted in FIG. 11) to accommodate the inclined side walls 72.

          In FIG. 13 is depicted another alternate construction of the arm 68 in which the side walls 72 are parallel to each other. This alternate construction  
15       differs from that shown in FIG. 11 in that the side walls 72 are sufficiently close to, or in contact with, the recesses 82 so that the clamp portion 80 may be welded to the side walls at the recesses, thereby further strengthening the connection between the sleeve 78 and the arm 68.

          Of course, a person skilled in the art would, upon a careful consideration  
20       of the above description of representative embodiments of the invention, readily appreciate that many modifications, additions, substitutions, deletions, and other changes may be made to these specific embodiments, and such changes are

contemplated by the principles of the present invention. Accordingly, the foregoing detailed description is to be clearly understood as being given by way of illustration and example only, the spirit and scope of the present invention being limited solely by the appended claims and their equivalents.

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